A-19

Nonlinear Strain Generation in Ultrafast Laser-excited Semiconductors

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We have investigated the laser fluence dependence of the lattice response of indium antimonide and gallium arsenide crystals to ultrafast laser absorption using time-resolved x-ray diffraction. In both materials, slow thermal cooling follows an initial acoustic strain impulse. For indium antimonide, where the laser photon energy is significantly above the band gap, we find that both acoustic and thermal lattice expansions increase linearly with increasing laser fluence. The band gap and photon energy are much closer in gallium arsenide where we find that while the thermal response remains linear with laser fluence, the magnitude of the acoustic impulse is highly nonlinear, exhibiting an initial saturation and recovery far below the laser damage threshold limit. Several hypotheses have been put forward of different nonlinear processes that could lead to this behavior. To place additional constraints on these models, we have upgraded the data acquisition system at APS 7-ID to record high-resolution diffraction lineshapes that can be directly compared to semiconductor strain models incorporating the transport of sound, heat, and charge.